A solution of the salt (about 1 in 1,000) in diluted sulphuric acid should not exhibit more than a faint blue fluorescence (absence of more than traces of the *sulphates of quinine* or *quinidine*).

If 1 gm. of the salt be dried at 100° C. (212° F.) until it ceases to lose weight, the residue, cooled in a desiccator, should weigh not less than 0.920 gm. (absence of an *undue amount of water*).

If 0.5 gm. of the salt be macerated, with frequent agitation, at the ordinary temperature, with 20 c.c. of distilled water, 0.5 gm. of potassium sodium tartrate then added, the maceration continued, under repeated agitation, for one hour at 15° C. (59° F.), and the mixture then filtered, the addition of one drop of ammonia water to the filtrate should not produce more than a slight turbidity (absence of more than small proportions of the *sulphates of cinchonine* or *quinidine*).

Quinidine Sulphate ($(C_{20}H_{24}N_2O_2)_2H_2SO_4 + 2H_2O$) is soluble in 100 parts of water or in 8 of alcohol, and is neutral or faintly alkaline.

Quinoidine, *Chinoidine*, or *Black Stick*, is a blackish, resinous, alkaloidal mass precipitated from the mother liquor and without definite composition. It is nearly equal in efficacy to quinine, and may often be used in the same dose as quinine in chronic malaria, when other alkaloids have failed, or when quinine cannot be used.

Febrifuge is a name applied to an alkaloidal mass manufactured in India as a cheap substitute for quinine for home consumption. One form is made of the total alkaloids of red bark, another as a by-product after the extraction of quinine, with the addition of the alkaloids of some hybrid bark. It is used on an immense scale. Its composition is reported by Hooper (*Pharmacographia Indica*) as quinine 15.1 per cent., cinchonidine 29 per cent., cinchonine 33.5 per cent., amorphous alkaloids 17 per cent. It is a pale yellowish-white powder, of peculiar odor. The dose is slightly larger than that of quinine.

Unofficial Cinchona Barks.

Only two of these are important, namely, Pale Bark and Maracaibo Bark.

Pale Bark.—This is the product of *Cinchona officinalis* L. and its several varieties. These vary so greatly in appearance that there are various forms of this bark recognized, as Crown, Huanuco, Cuenca, Loxa or Loja. The native bark came from Ecuador, and still does so in rather large amounts. It comes from large shrubs and occurs in rather crooked, thin quills, from the thickness of a lead pencil to that of the finger, and is rather thick for the size of the quill. It is generally of a dark brown, the Huanuco a rather light brown, and is very apt to be excessively shaggy with lichens, when it is highly prized and really contains more alkaloid, as a result of the exclusion of light during growth. It is less bitter than the other barks. It and various hybrids have come largely into cultivation, but this cultivation is not now continued on the same scale. These hybrid forms grow much larger, the quills becoming as large as an ordinary calisaya. They retain their proportionally greater thickness. They are usually of a dingy gray and the fissures are wide and gaping. The color of the powder is very light, giving the name "pale." This bark (if typical) usually contains about three per cent. of alkaloids, one-half to nearly two-thirds being quinine. It is chiefly consumed in Southern Europe. It was formerly official, and its fluid extract is still a favorite with many American physicians. This preference is however erroneous, unless a double dose is given to secure the same effect.

Maracaibo Bark.—This is from one of the most northerly growing species. What that species is, is not certain. The bark occurs in warped, chip-like, thick pieces commonly as large as the hand, and is of coarsely striated structure, and hard and heavy. It is of a bright but pale yellow, with silvery soft patches of periderm easily scraped off with the thumb-nail. Its only interest is because many ignorant pharmacists purchase it, under the name of "yellow bark," for calisaya. It is quite worthless except as a vegetable bitter, containing a great amount of resin, but practically no quinine or other valuable alkaloid.

The other unofficial barks, Cuprea, Pitaya, Gray, Hard, and Soft Colombian, Hard and Fibrous Carthagena, Hamalies, Cuzco, Cocola, Pajinal, are in the market, if at all, only as relics. They are no longer collected. When cinchona was valuable, great quantities of these were accumulated in London, and when the price fell they were stored to await a favorable market. This never came, and many tons are still there, for which their owners would be glad to take five per cent. of the cost price. From time to time small quantities of these are worked off upon ignorant or careless buyers, but their use can be regarded only as objectionable.

Remijia.—One of these, Cuprea Bark, is the product of the related genus Remijea and contains a small amount of quinine.

The following composition table by Dr. Bolles, taken from the last edition of this work, is of interest:

1. Alkaloids.

Name.	Discovery.	Composition.	Source.
Quinine	Pelletier and Caventou, 1820.	$C_{20}H_{24}N_2O_2$.	In all the best cinchonas, especially *C. Calisaya*, *Ledgeriana*, *officinalis*, *lancifolia*, *pitayensis*, etc., associated with cinchonine, etc.
Quinidine	Henry and Delondre, 1833.	Same formula	*C. pitayensis* and other good species.
Cinchonine	Pelletier and Caventou, 1820.	$C_{19}H_{22}N_2O_2$.	Red bark, *C. succirubra*, also in most of the others, common and abundant.
Cinchonidine.	Winckler, 1847..	Same formula	*C. tucujensis*, also in other species.
Homocinchonidine.	Hesse, 1877.....	$C_{19}H_{22}N_2O_2$.	South American red bark.
Quinamine	Hesse, 1872.....	$C_{19}H_{24}N_2O$.	*C. Ledgeriana*, *officinalis*, etc., also in *Remijia*.
Cinchamidine	Hesse, 1881.....	$C_{20}H_{26}N_2O$.	From the mother liquor of homocinchonidine. Frequently present in commercial cinchonidine.
Aricine	Pelletier and Coriol, 1829 ...	$C_{23}H_{26}N_2O_4$.	*C. pubescens*, etc., Arica or cusco bark.
Cusconine	Hesse, 1877.....	$C_{23}H_{26}N_2O_4$.	Accompanying the above.
Cusconidine	Hesse, 1877.....	Not analyzed.	
Cuscamine	Hesse, 1880 (...	Not analyzed.	*C pelletieriana* ("cusco bark").
Cuscamidine	Hesse, 1880 (...		
Paricine	Winckler, 1844..	.....	*C. succirubra* (Hesse, 1877).

2. Acids.

Cinchonic acid, kinic acid.	Hoffman, 1790..	$C_7H_{12}O_6$.	In all cinchonas and many other plants. A widely distributed vegetable acid.
Chinovic acid.	Hlasiwetz.....	$C_{24}H_{38}O_4$.	In cultivated cinchonas; probably more general. Also in Tormentilla.
Cinchotannic acid.	Berzelius	.....	All cinchonas.

3. Neutral and Miscellaneous.

Chinovin. A glucoside.	Pelletier and Caventou, 1821.	$C_{30}H_{38}O_8$.	Cinchonas, Remijias, and other *Cinchoneæ*.
Cinchona red.	Reuss, 1812.....	$C_{28}H_{32}O_{14}$.	All cinchonas, especially the red.
Lignoin	Reichel, 1856 ...	$C_{20}H_{22}NO_8$.	Cinchonas—doubtful substance.
Cinchocerotin.	Kerner, 1859 ...	$C_{27}H_{48}O_2$.	Calisaya.
Water			

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CINCINNATI, the chief city of Ohio, is situated on the north bank of the Ohio River. "It is surrounded by hills from 400 to 465 feet in height, forming one of the most beautiful amphitheatres on the continent, from whose hilltops may be seen the splendid panorama of the cities below, and the winding Ohio" (Appleton's "Guide to the United States and Canada"). It is a city of three hundred thousand or more inhabitants, more than a third of whom are Germans or of German parentage. The chief public park is Eden Park, situated on a hill affording a striking view of the city, the valley of the Ohio, and the surrounding country. The climate is indicated by the accompanying chart.

Climate of Cincinnati, Ohio.—Latitude, 39° 6′; Longitude, 84° 30′. Period of Observations, December 1st, 1870, to December 31st, 1883.

Data.	January.	July.	Year.
Temperature (Fahr.)			
Average or normal	34.4°	78.3°	55.90°
Average daily range	14.0	16.3	
Mean of warmest	41.4	86.8	
Mean of coldest	27.4	70.5	
Highest or maximum	69.0	103.5	
Lowest or minimum	−10.0	38.2	
Humidity—			
Average relative	72.3%	64.4%	66%
Precipitation—			
Average in inches	3.54	4.29	44.36
Wind—			
Prevailing direction	S.W.	S.W.	N.W.
Average hourly velocity in miles	6.4	4.8	9.8
Weather—			
Average number of clear days	4.8	9.2	94.9
Average number of fair days	10.2	12.2	140.4
Average number of clear and fair days	15.0	21.4	235.3

E. O. Otis.

CINCINNATI ARTESIAN WELL.—Hamilton County, Ohio. This well is located at the Cincinnati gas-works, and is 1,245 feet in depth. There is a continuous flow of water. The following analysis is by E. S. Wayne:

One United States Gallon Contains:

Solids.	Grains.
Magnesium carbonate	8.14
Calcium carbonate	17.33
Potassium sulphate	27.27
Sodium chloride	519.90
Magnesium chloride	18.14
Calcium chloride	22.26
Potassium chloride	3.27
Magnesium bromide	.26
Magnesium iodide	.19
Iron oxide	.37
Silica	.49
Total	617.32
Gases.	**Cu. in.**
Sulphureted hydrogen	7.76
Carbonic acid	10.32

This is a very rich saline sulphureted water, and ought to be of value in the treatment of diseases for which such waters are used. *James K. Crook.*

CINNAMIC ACID AND CINNAMATES.—Cinnamic or *phenyl-acrylic* acid ($C_9H_8O_2$) results from oxidation of oil of cinnamon, the oil being chemically cinnamic aldehyde, and it also exists ready formed in conjunction with benzoic acid, to which it is closely related, in many balsams, such as the balsams of tolu, of Peru, and of benzoin. It can be formed synthetically also. Cinnamic acid is a colorless crystalline body, volatilizable without taste or smell, freely soluble in alcohol, but only feebly so in water (one-tenth per cent.). The commercial article is obtained chiefly from styrax.

Cinnamic acid is non-poisonous, and is said to resemble salicylic and benzoic acids in antiseptic power. It has been suggested as a practical antiseptic for use in surgical dressings. Lint, jute, etc., may be charged with the acid by soakage in an alcoholic solution. It has also been employed for the constitutional treatment of phthisis, by the intravenous injection, twice a week, of a few minims of a five-per-cent. emulsion of the acid. Such injection is practised upon a vein of the forearm, with proper antiseptic precautions, and the treatment continued for at least three months.

Cinnamic acid is oxidized readily into benzoic acid, and it is supposed that this action takes place in the human system, since the two acids have the same effect upon the urine and its constituents.

Sodium cinnamate is a salt freely soluble in water, and has been proposed as a substitute for cinnamic acid because of such free solubility. *Edward Curtis.*

CINNAMON.—The cinnamon products include cinnamon and cassia barks, cassia chips, cassia leaves and cassia flowers, and the oils distilled therefrom. They are all yielded by species of the genus *Cinnamomum* Blume, in the family *Lauraceæ*. The genus contains some fifty-four species, all natives of tropical Asia and Australasia. The section containing the camphor tree is markedly distinct, and would probably be better regarded as forming a separate genus. Many of the species yield useful products of minor importance, and these will be enumerated at the close of this article. Three species, two of them known, the third doubtful, yield the highly esteemed and official cinnamon barks, and will now be considered separately.

1. Ceylon Cinnamon, Cinnamomum Zeylanicum.—"The inner bark of the shoots of *Cinnamomum Zeylanicum* Breyne" (U. S. P.). This well-known species is a native of the hills and woods of the island of Ceylon. It has also been long cultivated in the same island, and it is from these cultivated plants that all the true cinnamon now comes. It has also been introduced into other islands of the Indian Ocean, and into the mainland of Asia, as well as into the West Indies, but it produces in these places inferior barks. On the cinnamon plantations the trees are trimmed down to make them send up sprouts from the base; these are allowed to grow until they are about two years old and 3 or 4 cm. in diameter, when they are cut, and the bark is peeled off in pieces about 30 cm. (1 ft.) in length. These strips are then put together in rolls and allowed to wilt for a day or so, when they are separated and each piece is laid upon a suitable stick around which it will fit, and the outer cellular layers of the bark are scraped off and rejected. The quills of inner bark so prepared constitute cinnamon, and are rolled together in successive layers until a solid cylinder about a metre long and 1.5 or 2 cm. thick is formed (1 yd. by 0.5 or 0.75 in.), of sometimes a dozen layers of brittle, splintery bark. The Pharmacopœia thus describes the bark:

"*Ceylon cinnamon* is in long, closely rolled quills, composed of eight or more layers of bark of the thickness of paper; pale yellowish brown; outer surface smooth, marked with wavy lines; inner surface scarcely striate; fracture splintery; odor fragrant; taste sweet and warmly aromatic."

This is altogether the finest, and in general the best cinnamon of the market, though it is not nearly so strong, sweet, or expensive as the third variety. If taken young and of good quality, it has scarcely a trace of bitterness and but little astringency. It contains only a moderate amount of sugar and mucilage. It yields a large percentage (up to five per cent.) of ash. It is rich in oil, yielding up to one and a half per cent., and this oil is very fragrant. The features of this cinnamon, as a perfuming and flavoring agent, are its delicacy and permanence. It is the only species official in the British Pharmacopœia.

2. Cassia Cinnamon, Cinnamomum Cassia, Cassia Lignea, Cassia Vera.—"The bark of the shoots of one or more undetermined species of Cinnamomum grown in China" (U. S. P.). In spite of this statement, the article is known to be the product of *C. Cassia* (Nees) Blume. Like Ceylon cinnamon, it is collected both from wild and from cultivated trees, mostly the latter. It comes from Southern China, and is therefore often called Chinese cinnamon. The name is a bad one, however, as it does not distinguish it from No. 3. The trees are cut down when about six years old, and the long straight

shoots, about an inch in thickness, are peeled in lengths of about a foot. Each quill is usually the bark from half the circumference. The outer bark is not carefully scraped away as in the last, but is roughly and imperfectly shaved off with an instrument resembling a spoke shave. The quills are dried and packed separately. The description of this species is as follows: "In quills of varying length and about 1 mm. or more in thickness; nearly deprived of the corky layer; yellowish brown; outer surface somewhat rough; fracture nearly smooth; odor fragrant; taste sweet and warmly aromatic." This variety tends much more to bitterness and astringency than the last. Its better grades also contain more sugar and gum. Its yield of oil is ordinarily less, and this is usually not quite so fine, though it is the ordinary commercial sort. The special feature of this cinnamon is its variability. Its best varieties are rather sweeter than the last in flavoring, but the taste does not endure so well. Its poorer varieties are scarcely fit for use. The best varieties are the "Java" and "Batavian." They are very carefully prepared from young shoots. The outer bark is entirely removed, the color is a pale yellow-brown, the taste fragrant, sweet, and very mucilaginous. The latter character rather disqualifies it for pharmaceutical uses, but makes it better, if anything, for culinary purposes. The poorest grades are the cheap "Chinese Mats." In preparing them, each packer has three lots of material to draw upon. First, some long quills of fair quality; second, some broken material and chips of very inferior grade; third, sand or other heavy foreign material. These he uses in regular proportions and packs neatly, with the good bark in a thin layer upon the outside. Two small rolls are sewn into a mat. Cassia is the cinnamon almost exclusively used in the household, and the most of this is of the poorer grades, besides which the ground article is enormously adulterated.

Saigon Cinnamon, Cinnamomum Saigonicum, "God's Cinnamon."—To this variety also the name *Chinese Cinnamon* is applied. "The bark of an undetermined species of Cinnamomum" (U. S. P.). We are entirely ignorant of the botanical origin of this variety. Although it has frequently been assumed that it is from the same plant which yields the last, its characters almost certainly prove the contrary. For many years we heard of a cinnamon in the unvisited regions of Southern China which was unknown in civilization, and of wondrously fine quality. Its curative properties were almost deified by the Chinese. At length some small lots were brought out, and it has now become a regular article of commerce. Little is known of the methods of its collection or drying. It comes in single quills of a foot in length, none of the outer bark being removed. These are tied neatly in bundles about ten inches in diameter. Each case contains rolls made up of bark of different respective thickness, the intermediate being the best. The thinnest is smoothish and of a dark red-brown. The others are gray or gray-brown and rough, the intermediate granular, the thickest fissured. Saigon cinnamon sometimes comes in chips of very thick bark, sometimes a third to a half inch thick. At its best, this entire thickness is free from astringency and bitterness, fragrant and very sweet, differing markedly in this character of the outer layers from either of the others. It is also peculiar in its sugary sweetness. Its aromatic property also is quite distinct, being biting rather than mild. Altogether, it is the sweetest and strongest of the cinnamons, but at the same time the least permanent as to flavor and odor. It is clearly nearer to cassia than to Ceylon cinnamon. Its best grade is much the most expensive variety of cinnamon. It is subject to substitution by a false article, very closely resembling it, both naturally and in its packing. This article is a cinnamon, and looks as though it might be selected from unpeeled cassia. The intermediate size is that adopted by the Pharmacopœia, and is thus described:

"In quills about 15 cm. long, and 10 to 15 mm. in diameter, the bark 2 or 3 mm. thick; outer surface gray or light grayish brown with whitish patches, more or less rough from numerous warts and some transverse ridges and fine longitudinal wrinkles; the inner surface cinnamon-brown or dark brown, granular and slightly striate; fracture short, granular, in the outer layer cinnamon-colored, and near the cork with numerous whitish striæ forming an almost uninterrupted line; odor fragrant; taste sweet, warmly aromatic, somewhat astringent."

Some other cinnamon species and products, including the oil of cinnamon, will be discussed at the close of the article.

Composition.—The general composition of the bark has already been given. The only constituent that can by any reasoning be classed as medicinally active is the oil, which exists in the proportion of one-half to one and one-half per cent.

Action and Uses.—Aside from its use as a condiment, and as an adjuvant in the pharmacy, its properties and uses are entirely those specified under the title of the oil.

Preparation.—The only medicinal preparation, strictly speaking, other than those of the oil, is the ten-per-cent. tincture, made from the Ceylon variety, the dose being 4 to 8 c.c. (fl. ʒ i.–ij.). The dose of powdered cinnamon of any variety is 0.5 to 2 gm. (gr. viij.–xxx.). Ceylon cinnamon enters into the aromatic powder, and cassia into the compound tinctures of cardamom, catechu, and lavender, but none of these are proper preparations of cinnamon as such. Saigon cinnamon enters into no preparation.

Cassia Chips.—These are the trimmings of cassia bark which cannot be utilized as cinnamon, but which yield a certain amount of oil upon distillation.

Cassia Buds or Cassia Flowers are the unripe fruits, not only of the species above named, but also of *C. Tamala* Nees ab Eberm. and *C. dulce* N. ab E. *C. daphnoides* Sieb. and Zucc. and *C. Loureirii* Nees yield a very poor quality of a false cinnamon. The leaves of *C. obtusifolium* Nees, *C. iners* Reinw., *C. nitidum* Hook., *C. Tamala* N. ab E., and some other species have been articles of commerce under the name of Malabathrum leaves. The bark of various species have found minor uses in medicine, chiefly as anti-diarrhœal agents, acting partly by their tannin and partly by the volatile oil.

Henry H. Rusby.

CINNAMON, OIL OF.—Oleum Cinnamomi. The origin of this oil has been sufficiently explained. Our Pharmacopœia directs that it be distilled from cassia cinnamon, not because that of Ceylon cinnamon is unsatisfactory, but because the two, if first class, are hardly to be distinguished, and practically all of the oil of commerce comes from cassia. Much of the commercial oil is said to be distilled from the leaves. While ordinary oil of cinnamon can be had for two or three dollars a pound, that of the Ceylon brings twenty, and is no better. The following is its official description:

"A yellowish or brownish liquid, becoming darker and thicker by age and exposure to the air, having the characteristic odor of cinnamon, and a sweetish, spicy, and burning taste. Specific gravity, 1.055 to 1.065 at 15° C. (59° F.). Soluble in an equal volume of alcohol, the solution being slightly acid to litmus paper; also soluble in an equal volume of glacial acetic acid. When shaken with a saturated solution of sodium bisulphite, it solidifies to a crystalline mass. If four drops of the oil, contained in a test tube, be cooled to 0° C. (32° F.), and then shaken with four drops of fuming nitric acid, crystalline needles or plates will be formed. If a portion of the oil be shaken with water, and the liquid passed through a wet filter, the clear filtrate should give, with a few drops of basic lead acetate T. S., a white turbidity, without a yellow color (absence of oil of cloves). If four drops of the oil be dissolved in 10 c.c. of alcohol, the subsequent addition of a drop of ferric chloride T. S. should produce a brown, but not a green or blue, color (absence of oil of cloves or of carbolic acid). If 1 c.c. of the oil be mixed with 3 c.c. of a mixture of three volumes of alcohol and one volume of water, a clear solution should result; and if to this solution there be gradually added 2 c.c. of a saturated solution of lead acetate in a mixture of three volumes

of alcohol and one volume of water, no precipitate should be produced (absence of petroleum, or of colophony)."

The active constituent of this oil is *cinnamic aldehyde*. It should contain not less than seventy-five per cent. of it, and eighty-five per cent. is easily attainable. Since the relative values of different samples are exactly proportional to the percentage of this substance, and since the latter can be purchased and its purity readily determined, a great gain would be made by using it instead of the oil. It is readily oxidized into cinnamic acid. Oil of cinnamon possesses the ordinary properties of volatile oils (see *Active Constituents of Plants*) and is peculiar among them because of its being generally regarded as the most agreeable, and because it is probably the most highly antiseptic of them all. The dose is ♏ i. to v. We have two official preparations, the water, strength one-fifth of one per cent. and dose 15 to 30 c.c. (ʒ ss.–i.), and the spirit, strength ten per cent. and dose 0.5 to 2 c.c. (8 to 30 m.).

Henry H. Rusby.

CINNAMYL-META-CRESOL. See *Hetocresol.*

CIRCULATION OF THE BLOOD.—I. Comparative and Historical Introduction.—The term circulation as applied to the blood was first used in physiology by Cesalpino (1569) to describe the true path taken by it in its passage from the right to the left side of the heart. The Galenic doctrine, according to which this passage was made by way of pores in the intraventricular septum, was accepted without question until Servetus (1553) and Vesalius (1555) established anatomically the soundness and impermeability of the septum of the heart. The idea of the actual path by way of the pulmonary vessels seems to have suggested itself immediately, this course being correctly described in the writings of Servetus and Columbo (1559); and although a pure surmise from the logical necessities of the case and unsupported by experimental proof, it quickly gained acceptance and was named "circulation."

By extension the term has come to be applied to the motion of the blood in animals generally, however irregular and variable this may be. The comparative physiologist speaks of the circulation of the blood even in those invertebrate animals in which neither heart nor vessels exist, and in which a sluggish ebb and flow of the blood through irregular tissue spaces and perivisceral cavities alone occurs, the movement being the result of contractions of the alimentary canal and the body generally. Etymologically the word circulation would be applicable only to the conditions found in the fishes, birds, and mammals. The accompanying diagrams of the vascular systems of the crayfish, fish, frog, and mammal will serve to illustrate some of the fundamental differences found in the animal series in respect to these organs.

As to the invertebrate type, represented here by the

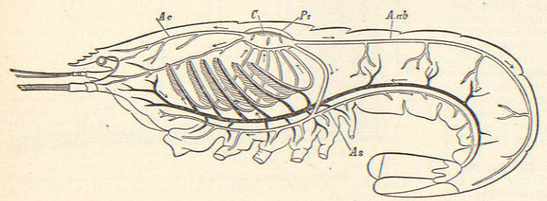

Fig. 1325.—Heart and Blood-Vessels and Gills of the Crayfish. *c*, Heart in a blood sinus, with *Ps*, several pairs of ostia; *Ac*, cephalic aorta; *A.ab*, abdominal aorta; *As*, sternal artery.

crayfish, two distinguishing peculiarities are to be noted. In the first place, the heart and blood-vessels do not form a closed system of channels. However highly developed the vascular system in them may be, it will be found that in some part or parts of the body the vessels terminate and the blood flows into so-called "lacunæ" or tissue spaces not bounded by any limiting membrane. This condition obliterates the distinction between blood and lymph and leads to the use of such terms as "hydrolymph" and "hæmolymph" for the blood of these animals. The other characteristic feature consists in the fact that the blood returns to the heart from the respiratory apparatus where one is present, instead of from the body generally, constituting a so-called "arterial heart."

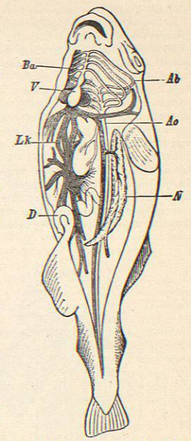

Fig. 1326.—Diagram of the Circulatory Organs of an Osseous Fish. *V*, Ventricle; *Ba*, aortic bulb, with the arterial arches which carry the venous blood to the gills; *Ao*, dorsal aorta, into which open the vessels from the gills or branchial veins, *Ab*; *N*, kidney; *D*, alimentary canal; *Lk*, portal circulation.

Compare in both these respects the diagrams of the circulation of the lobster (Fig. 1325) and fish (Fig. 1326). In the latter the system of vessels is a closed one, and the heart functions as a venous organ. In the air-breathing vertebrates further changes in the circulatory organs accompany the appearance of pulmonary respiration. The tubular heart of the fish, with its four consecutive chambers, is replaced by an organ with a median partition. In the frog (Fig. 1327) the right and left auricles are completely separated in this way, while the ventricle remains a single chamber. A partial ventricular septum of increasing proportions is found in the turtles, snakes, and lizards, becoming complete only in the highest of the reptilia, the crocodiles, as it is in birds and mammals.

The above variations in the structure of the heart are attended by certain changes in the arrangement and connections of the main vessels arising from it, especially as regards the extent of the communication between the aortic and pulmonary arteries. The result of both series of changes is to secure an increasing amount of separation between venous and arterial blood. The venous blood of the right auricle in frogs mingles rather freely with the arterial blood of the left auricle when they reach the common ventricle. This occurs, to a diminishing extent, as the interventricular septum develops; but even in the crocodilia, in which it is complete, the mixing of the two kinds of blood is not wholly avoided, since there remains a communication—the foramen of Panuzzi—between the right and left aortic arches.

In birds and mammals the motion of the blood again becomes a true circulation, and a particle of it starting at any point of the system must make a complete circuit before it passes that point again. Accomplishing this it will traverse at least two capillary networks, the systemic and the respiratory, as was the case in fish also; but besides, it passes twice through the heart, in this respect differing from the fishes. The venous heart of the latter has been replaced by a double organ with a right venous side which transfers the blood from the